

We claim:

- 1 1. An interconnect structure formed on a substrate, the structure comprising:
2 a dielectric layer overlying the substrate;
3 a hardmask layer on said dielectric layer, said hardmask layer having a
4 top surface;
5 at least one conductor embedded in said dielectric layer and having a
6 surface coplanar with the top surface of said hardmask layer;
7 a first cap layer on said at least one conductor and on said hardmask
8 layer; and
9 at least one second cap layer on said first cap layer.
- 1 2. The interconnect structure according to Claim 1, wherein said first cap layer is
2 formed by a high density plasma chemical vapor deposition (HDP CVD)
3 process.
- 1 3. The interconnect structure according to Claim 1, wherein said second cap layer
2 is formed by a plasma-enhanced chemical vapor deposition (PE CVD) process.
- 1 4. The interconnect structure according to Claim 1, further comprising a
2 conductive liner disposed between said conductor and said dielectric layer.
- 1 5. The interconnect structure according to Claim 1, further comprising an
2 adhesion promoter layer disposed between said dielectric layer and the
3 substrate.
- 1 6. The interconnect structure according to Claim 1, wherein said dielectric layer is
2 formed of an organic thermoset polymer having a dielectric constant of about
3 1.8 to about 3.5.

- 1 7. The interconnect structure according to Claim 6, wherein said dielectric layer is
2 formed of a polyarylene ether polymer.
- 1 8. The interconnect structure according to Claim 1, wherein said first cap layer is
2 formed of a dielectric material selected from the group consisting of silicon
3 nitride, silicon carbide and boron nitride.
- 1 9. The interconnect structure according to Claim 1, wherein said first cap layer is
2 formed of silicon nitride having a composition of about 40 atomic % silicon,
3 about 52 atomic % nitrogen, and about 8 atomic % hydrogen.
- 1 10. The interconnect structure according to Claim 1, wherein said second cap layer
2 is formed of a dielectric material selected from the group consisting of silicon
3 nitride, silicon carbide and boron nitride.
- 1 11. The interconnect structure according to Claim 1, wherein said second cap layer
2 is formed of silicon nitride having a composition of about 37 atomic % silicon,
3 about 48 atomic % nitrogen, and about 15 atomic % hydrogen.
- 1 12. The interconnect structure according to Claim 1, wherein said second cap layer
2 is formed of silicon carbide having a composition of about 27 atomic %
3 silicon, about 36 atomic % carbon, and about 37 atomic % hydrogen.
- 1 13. The interconnect structure according to Claim 1, wherein said second cap layer
2 is formed of amorphous hydrogenated nitrogenated silicon carbide having a
3 composition of about 22 to 30 atomic % silicon, about 15 to 30 atomic %
4 carbon, about 10 to 22 atomic % nitrogen and about 30 to 45 atomic %
5 hydrogen.

- 1 14. The interconnect structure according to Claim 1, wherein said conductive
2 material is copper.
- 1 15. The interconnect structure according to Claim 1, wherein said second cap layer
2 comprises a plurality of thin films each formed by a plasma-enhanced chemical
3 vapor deposition (PE CVD) process.
- 1 16. The interconnect structure according to Claim 15, wherein the plurality of thin
2 films comprises at least one silicon nitride film and at least one film selected
3 from the group consisting of silicon oxide, silicon carbide, boron nitride,
4 silicon oxycarbide and silicon oxycarbonitride.
- 1 17. The interconnect structure according to Claim 1, wherein said first cap layer
2 has a thickness of about 25 to 700 Å.
- 1 18. The interconnect structure according to Claim 1, wherein said second cap layer
2 has a thickness of about 100 to 1000 Å.
- 1 19. The interconnect structure according to Claim 15, wherein each thin film has a
2 thickness of about 50 Å.
- 1 20. A method for forming an interconnect structure on a substrate, the method
2 comprising the steps of:
3 depositing a dielectric material on the substrate, thereby forming a
4 dielectric layer,
5 depositing a hardmask material on said dielectric layer, thereby forming
6 a hardmask layer, said hardmask layer having a top surface;
7 forming at least one opening in said dielectric layer;

8 filling said opening with a conductive material, thereby forming at least
9 one conductor, said conductor having a surface coplanar with the top surface of
10 said dielectric layer;

11 depositing a first material on said conductor, thereby forming a first cap
12 layer; and

13 depositing a second material on said first cap layer, thereby forming a
14 second cap layer.

1 22. The method according to Claim 20, wherein said second material is deposited
2 by a plasma-enhanced chemical vapor deposition (PE CVD) process.

1 21. The method according to Claim 20, wherein said first material is deposited by
2 a high density plasma chemical vapor deposition (HDP CVD) process.

1 23. The method according to Claim 21, wherein said first material is silicon
2 nitride, and said HDP CVD process includes placing the substrate into a reactor
3 chamber at a pressure of about 0.1 milli-torr to about 50 milli-torr and at a
4 temperature of about 200°C to about 500°C, and exposing the substrate to at
5 least one gas selected from the group consisting of silane, nitrogen, argon and
6 helium.

1 24. The method according to Claim 22, wherein said second material is silicon
2 nitride, and said PE CVD process includes placing the substrate into a reactor
3 chamber at a pressure of about 0.1 torr to about 10 torr and a temperature of
4 about 150°C to about 500°C, and exposing the substrate to at least one gas
5 selected from the group consisting silane, ammonia, nitrogen and helium.

1 25. The method according to Claim 20, wherein said first material is deposited by
2 a HDP CVD process under vacuum and said second material is deposited by a

3 PE CVD process under vacuum, without exposing the substrate to
4 atomospheric pressure prior to deposition of said second material.

1 26. The method according to Claim 20, further comprising, after formation of said
2 conductor and prior to deposition of said first material, the step of:
3 performing a plasma pre-cleaning process which includes heating the
4 substrate to a temperature of about 150°C to about 500°C and exposing the
5 substrate to a source of hydrogen for a time of about 5 to about 500 seconds.